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The Naval Research Laboratory

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THE NAVAL RESEARCH LABORATORY

"I believe [that] the Government should maintain a great research laboratory, jointly under military and naval and civilian control. In this could be developed the continually increasing possibilities of . . . all the technique of naval progression ....

"When the time came, if it ever did, we could take advantage of the knowledge gained through this research work and quickly produce the very latest and most efficient instruments ...."

Thomas A. Edison
The New York Times Magazine
May 30, 1915

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THE NAVAL RESEARCH LABORATORY

Our Heritage

Today, when government and science seem inextricably linked, when virtually no one questions the dependence of national defense on the excellence of national technical capabilities, it is noteworthy that in-house defense research is relatively new in our Nation's history. The Naval Research Laboratory (NRL), the first modern research institution created within the United States Navy, began operations in 1923.

Thomas Edison's Vision—The first step came in May 1915, a time when Americans were deeply worried about the great European war. Thomas Edison, asked by a *New York Times* correspondent to comment on the conflict, argued that the Nation should look to science. "The Government," he proposed in a published interview, "should maintain a great research laboratory.... In this could be developed...all the technique of military and naval progression without any vast expense." Secretary of the Navy Josephus Daniels seized the opportunity created by Edison's public comments to enlist Edison's support. He agreed to serve as the head of a new body of civilian experts—the Naval Consulting Board—to advise the Navy on science and technology. The Board's most ambitious plan was the creation of a modern research facility for the Navy. Congress allocated $1.5 million for the institution in 1916, but wartime delays and disagreements within the Naval Consulting Board postponed construction until 1920.

The Laboratory's two original divisions, Radio and Sound, pioneered in the fields of high-frequency radio and underwater sound propagation. They produced communications equipment, direction-finding devices, sonar sets, and, perhaps most significant of all, the first practical radar equipment built in this country. They also performed basic research, participating, for example, in the discovery and early exploration of the ionosphere. Moreover, the Laboratory was able to work gradually toward its goal of becoming a broadly based research facility. By the beginning of World War II, five new divisions had been added: Physical Optics, Chemistry, Metallurgy, Mechanics and Electricity, and Internal Communications.

The War Years and Growth—Total employment at the Laboratory jumped from 396 in 1941 to 4400 in 1946, expenditures from $1.7 million to $13.7 million, the number of buildings from 23 to 67, and the number of projects from 200 to about 900. During WWII, scientific activities necessarily were concentrated almost entirely on applied research. New electronics equipment—radio, radar, sonar—was developed. Countermeasures were devised. New lubricants were produced, as were antifouling paints, luminous identification tapes, and a sea marker to help save survivors of disasters at sea. A thermal diffusion process was conceived and used to supply some of the ^{235}U isotope needed for one of the first atomic bombs. Also, many new devices that developed

The original Naval Research Laboratory in 1923 among the farmlands of Blue Plains as viewed from the Potomac River

from booming wartime industry were type tested and then certified as reliable for the Fleet.

NRL Reorganizes for Peace—Because of the major scientific accomplishments of the war years, the United States emerged into the postwar era determined to consolidate its wartime gains in science and technology and to preserve the working relationship between its armed forces and the scientific community. While the Navy was establishing its Office of Naval Research (ONR) as a liaison with and supporter of basic and applied scientific research, it was also encouraging NRL to broaden its scope and become, in effect, its corporate research laboratory. There was a transfer of NRL to the administrative oversight of ONR and a parallel shift of the Laboratory's research emphasis to one of long-range basic and applied investigation in a broad range of the physical sciences.

However, rapid expansion during the war had left NRL improperly structured to address long-term Navy requirements. One major task—neither easily nor rapidly accomplished—was that of reshaping and coordinating research. This was achieved by transforming a group of largely autonomous scientific divisions into a unified institution with a clear mission and a fully coordinated research program. The first attempt at reorganization vested power in an executive committee composed of all the division superintendents. This committee was impracticably large, so in 1949 a civilian director of research was named and given full authority over the program. Positions for associate directors were added in 1954.

The Breadth of NRL—During the years since the war, the areas of study at the Laboratory have included basic research concerning the Navy's environments of Earth, sea, sky, and space. Investigations have ranged widely from monitoring the sun's behavior, to analyzing marine atmospheric conditions, to measuring parameters of the deep oceans. Detection and communication capabilities have benefited by research that has exploited new portions of the electromagnetic spectrum, extended ranges to outer space, and

provided means of transferring information reliably and securely, even through massive jamming. Submarine habitability, lubricants, shipbuilding materials, fire fighting, and the study of sound in the sea, have also been steadfast concerns.

The Laboratory has pioneered naval research into space, from atmospheric probes with captured V-2 rockets, through direction of the Vanguard project—America's first satellite program—to involvement in such projects as the Navy's Global Positioning System. As part of the SDI Program, the Low-Power Atmospheric Compensation Experiment (LACE) satellite was designed and built by NRL. Today, NRL is the Navy's lead laboratory in space systems research, fire research, tactical electronic warfare, microelectronic devices, and artificial intelligence. NRL has also evaluated new issues, such as the effects of intense radiation and various forms of shock and vibration on aircraft, ships, and satellites.

NRL scientists and engineers produced a number of important scientific and technical innovations within the last year. One team of Laboratory scientists developed a technique for study of the detection of light by thin films of high-T_c metal oxide superconductors. Other researchers have produced a process for development of 20-kg heavy-metal fluoride glass windows, the largest fluoride glass windows yet made. Scientists at the Underwater Sound Reference Detachment have developed a reliable underwater electrical cable connector that increases the life of sonar devices; they have also produced an inexpensive closed-chamber test facility for shock testing naval sonar transducers. A compact, lightweight, high-current modified betatron accelerator that may have important shipboard, commercial, and environmental applications, was developed at the Laboratory. This work demonstrates for the first time that cyclic accelerators can confine injected electron beams with currents in excess of 1000 amperes for a period of several thousand revolutions. NRL scientists worked on developing means of verifying undersea volcanic eruptions that accompany underwater earthquakes. A scale model Sea Launch and Recovery (SEALAR) vehicle was successfully tested in a drop test for the first time. Other laboratory researchers developed a highly sensitive and precise instrument to measure the coefficients of thermal expansion in materials. This apparatus will be useful in measuring the stability of space optics. Several NRL-designed experiments went aloft on the Combined Release and Radiation Effects Satellite (CRRES) launched by NASA in July 1990. The CRRES is designed to provide improved

NRL's Heavy Ions in Space (HIIS) Experiment, which was one of 57 experiments aboard NASA's Long Duration Exposure Facility, was retrieved from space by the crew of the Space Shuttle Columbia on January 12, 1990. See article on p. 196.

knowledge of ionospheric and magnetospheric phenomena. A new Low-Altitude/Airspeed Unmanned Research Aircraft (LAURA) was developed to carry electronic warfare payloads for long flight at shiplike speeds. Also new in 1990 was a laboratory Epi-Center established to promote work in the combination of magnetic and semiconducting integrated circuitry. A Human-Computer Interaction Laboratory (HCIL) was founded to investigate improved human-computer interaction in information systems. In related work, NRL scientists investigated methods by which computer users can communicate commands to computers through eye movements.

One goal, however, has guided NRL's diverse activities through the years—to conduct pioneering scientific research and development that will provide improved materials, equipment, techniques, systems, and operations for the Navy, for the Department of Defense (DoD), and for the U.S. Government.

NRL Today

ORGANIZATION AND ADMINISTRATION

The position of NRL within the Navy is that of a field command under the Chief of Naval Research.

Heading the Laboratory with joint responsibilities are the naval commanding officer, Capt. John J. Donegan, Jr., USN, and the civilian director of research, Dr. Timothy Coffey. Line authority passes from the commanding officer and the director of research to five associate directors of research and the director of one technology center. Research is performed in the following areas:

- General Science and Technology
- Warfare Systems and Sensors Research
- Materials Science and Component Technology
- Naval Center for Space Technology.

Further details of the Laboratory's organization are given on the organizational chart appearing in the "General Information" section.

NRL operates as a Navy Industrial Fund (NIF) activity. As a NIF activity, all costs, including overhead, must be charged to various research projects. Funding in 1990 came from the Chief of Naval Research, the Naval Systems Commands, and other government agencies, such as the Defense Advanced Research Projects Agency, the Department of Energy, and the National Aeronautics and Space Administration as well as several nongovernment activities. NRL's relationship with its sponsoring agencies, both inside and outside DoD, is defined by a comprehensive policy on interagency support agreements.

Besides funding for scientific work, NRL receives Navy monies for general construction, maintenance, and operations.

PERSONNEL DEVELOPMENT

At the end of 1990, NRL employed 3680 personnel—47military officers, 67 enlisted men and women, and 3566 civilians. In the research staff, there are 768 employees with doctorate degrees, 392 with masters degrees, and 652 with bachelors degrees. The support staff assists the research staff by providing administrative, computer-aided designing, machining, fabrication, electronic construction, publication, personnel development, information retrieval, large mainframe computer support, and contracting and supply management services.

Opportunities for higher education and other professional training for NRL employees are available through several programs offered by the

NRL today as viewed from the east

Employee Development Branch. These programs provide for graduate work leading to advanced degrees, advanced training, college course work, short courses, continuing education, and career counseling. Graduate students, in certain cases, may use their NRL research for thesis material.

For non-NRL employees, several post-doctoral research programs exist. There are also cooperative education agreements with several universities, summer and part-time employment programs, and various summer and interchange programs for college faculty members, professional consultants, and employees of other government agencies.

NRL has active chapters of Women In Science and Engineering, Sigma Xi, Toastmaster's International, and the Federal Executive and Professional Association. Three personal computer clubs meet regularly—Edison Atari, NRL IBM-PC, and Edison Commodore. An amateur radio club, a drama group—the Showboaters, and several sports clubs are also active. NRL has a recreation club that provides swimming, sauna, whirlpool bath, gymnasium, and weight-room facilities. The recreation club also offers classes in martial arts, aerobics, swimming, and cardio-pulmonary resuscitation.

A community outreach program at NRL provides tutoring for local students, science fair judging, participation in high school and college career day programs, an art and essay contest during Black History Month, student tours of NRL, and a Christmas party for disadvantaged children with gifts donated by Laboratory employees.

NRL has an active, growing Credit Union with assets of $118 million and a membership numbering 15,250. Public transportation to NRL is provided by Metrobus.

For more information, see the *NRL Review* chapter entitled "Programs for Professional Development."

SCIENTIFIC FACILITIES

In addition to its main campus of about 130 acres and 152 buildings, NRL maintains 12 other

research sites including a vessel for fire research and a Flight Support Detachment. The many diverse scientific and technological research and support facilities are described in the following paragraphs.

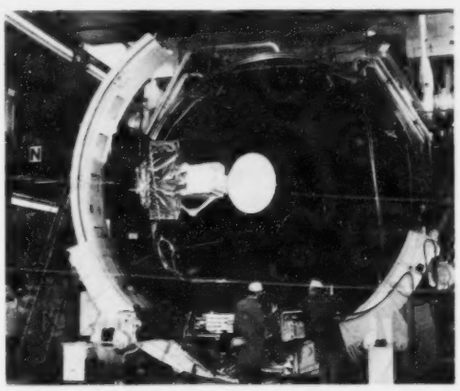
Research Facilities

• Space Science

NRL is the Navy's main laboratory for conducting basic research and development in the space sciences. The Space Science Division has a number of commitments for space experiments in the areas of upper atmospheric, solar, and astronomical research aboard NASA, DoD, and other space projects. Division scientists are involved in major research thrusts that include remote sensing of the upper atmosphere by using ultraviolet sensing, studies of the solar atmosphere by using spectrographic techniques, and studies of astronomical radiation ranging from the ultraviolet through the cosmic rays. The division maintains facilities to design, construct, assemble, and calibrate space experiments. A network of VAX computers, super minicomputers, image processing hardware, a PDS microdensitometer, and Cray and Connection Machine access are used to analyze and interpret space data.

• Center for Advanced Space Sensing

The Center for Advanced Space Sensing conducts a program of basic research, science, and applications to develop new concepts for sensors and imaging systems for objects and targets on the Earth and in the near-Earth environment, as well as in deep space. The research, both theoretical and experimental, leads to discovering and understanding the basic physical principles and mechanisms that give rise to the background environmental emissions and targets of interest and to absorption and emission mechanisms of the intervening medium. Accomplishing this research requires the development of sensor systems technology. The development effort includes active and passive sensor systems used for the study and analysis of the physical characteristics of phenomena that evolve from naturally occurring background radiation, such as that caused by the Earth's atmosphere and oceans and man-made or induced phenomena, such as ship/submarine hydrodynamic effects. The research includes theory, laboratory, and field experiments leading to ground-based, airborne, or space systems for use in remote sensing, astrometry, astrophysics, surveillance, nonacoustic ASW, and improved meteorological/oceanographic support systems for the operational Navy. Special emphasis is given to developing space-based platforms and exploiting existing space systems.



The MAS flight instrument is shown here entering a large thermal vacuum chamber and being readied for a space flight in June 1991. The instrument spectrometer was designed and fabricated in NRL's newly established Center for Advanced Space Sensing.

• Computational Physics and Fluid Dynamics

The Laboratory for Computational Physics and Fluid Dynamics (LCP&FD) has developed a Graphical and Array Processing System (GAPS). The system provides communications and common memory for large simulations on parallel array processors and immediate displays of results from other sources on high-resolution, high-speed graphics monitors. The system is front ended by two VAX 11/780s that provide control and

communication to other sites at NRL and outside laboratories. A 1.4-gigabyte high-speed disk is incorporated for simulations storage and replay. The computational engines are six 30-megaflop array processors supported by a vectorizing FORTRAN compiler. The current graphics devices are a Tektronix and a Metheus with 1024 × 1280 color raster resolution and high-speed block data transfer capability, and an IRIS 4D vector display. A 64-million word Convex C210 has recently been installed and incorporated into the NRL network.

The LCP&FD also maintains fluid dynamic laboratory facilities that include a 30-m wind/wave tank to study nonlinear ocean wave processes and fluid/structure interactions; a 20-m stratified tow channel to study geophysical flows, jets, and wakes; and blow-down water tunnels to study hydroacoustics, turbulent boundary layers, and non-Newtonion flows. Experimental efforts using these facilities are supported by flow measurement systems including multicomponent laser velocimeters and anemometers; digital image processing of flow visualization; hydrophones; imaging infrared radiometers; and a variety of microwave radar measurement systems for remote sensing studies of hydrodynamic processes. On-line experiment control, data acquisition, and processing are achieved with a central HP1000 system or one of a number of smaller, portable units.

• Condensed Matter and Radiation Sciences

Ion Implantation Facility—The facility consists of a 200-keV ion implanter with specialized ultrahigh vacuum chambers and associated in situ specimen analysis instrumentation. The facility is used to develop advanced surface treatments of materials to modify their properties and improve corrosion and wear resistance.

3-MeV Tandem Van de Graaff—This facility is used to study charged particle radiation damage effects such as occur in space, to perform Rutherford backscattering spectroscopy and nuclear reaction analysis to provide high-sensitivity composition depth profiles, and to perform MeV energy implants in materials.

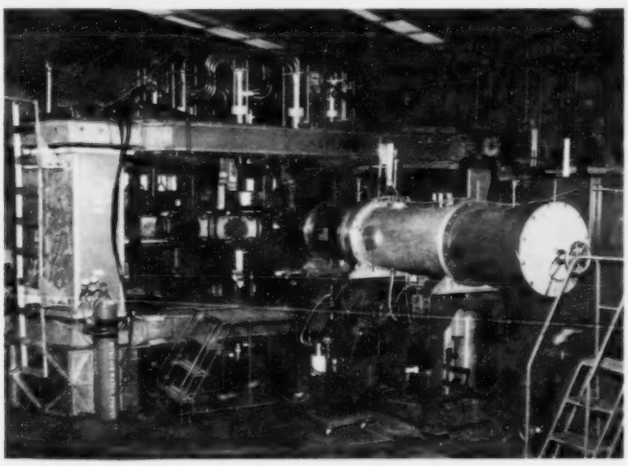
60-MeV Electron Linear Accelerator (LINAC)—The LINAC produces intense electron beams with 10 to 65 MeV energies. Pulse rates from 1 to 360 s and widths from 50 ns to 1.4 ms are selectable. This facility is widely used to study radiation effects on microelectronics and materials for both NRL and other important DoD satellite and missile programs. It is also used to study radiation effects on the new, high-critical-temperature superconductors. Single beam pulses can be analyzed and stored in a fast multichannel digitizer system.

Hypervelocity Impact Facilities—Three facilities are used for ballistics research at speeds exceeding 6 km/s with toxic or explosive targets. The projectile velocity, orientation, and dynamic projectile-target interaction can be measured.

Synchrotron Radiation Facility—An intense monochromatic X-ray photon source, tunable from 10 eV to 12 keV, is available on the NRL-developed beam lines at the National Synchrotron Light Source at Brookhaven National Laboratory. Environmental target chambers can span a pressure range from ambient to several hundred kbar and temperatures from 10 to 1500 K. A six-circle computer controlled goniometer is used to control and position targets.

• Plasma Physics

The Plasma Physics Division is the major center for in-house Navy and DoD plasma physics research. The division conducts a broad experimental and theoretical program in basic and applied research in plasma physics, which includes laboratory and space plasmas, pulsed-power sources, intense electron and ion beams, atomic physics, laser physics, and numerical simulations. The facilities include an extremely high-power laser, PHAROS III, for the laboratory simulation of space plasmas and high-latitude nuclear

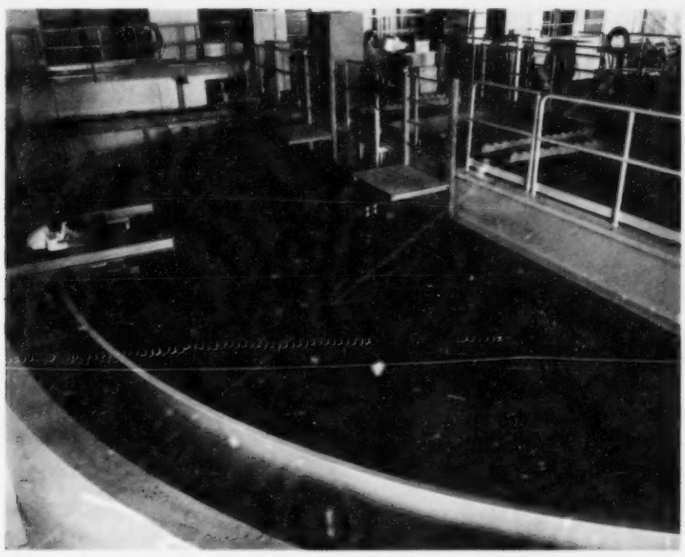


This compact, lightweight, high-current torodial accelerator was recently developed by scientists of the Plasma Physics Division. It has potential commercial and environmental applications, such as generation of high-power microwaves, sterilization of pharmaceuticals and potable water, sludge disinfection, vulcanization of rubber, crosslinkage of polymers, and cracking of crude oil.

explosion effects studies. The division has developed a variety of pulsed power sources to generate electron and ion beams, powerful discharges, and various types of radiation. The largest of these pulsers, GAMBLE II, is used to study the production of megampere electron beams and for producing very hot, high-density plasmas. Other generators are used to produce particle beams that are injected into magnetic fields and/or cavities to generate intense microwave pulses. A charged-particle-beam (CPB) propagation facility exists for testing advanced CPB propagation (both endo- and exoatmospheric) concepts. A 5-MW generator injects pulses of electron current into preheated ionization channels to study the effectiveness of propagation under various conditions. This division also operates a modified betatron facility for studying methods to accelerate high-current electron beams to energies in the 25- to 50-MeV range.

• Acoustics

NRL's facilities in support of acoustical investigations are located at the main Laboratory site and in Orlando, Florida, at the Underwater Sound Reference Detachment (USRD). At the main Laboratory site, there are three research tanks instrumented to study echo characteristics of targets and to develop devices. There is also an underwater acoustic holography facility for research in acoustic fields and a water tunnel having a large blow-down channel with a 15-m test section used for acoustic and flow-induced vibration studies of towed line arrays and flexible cables. NRL is investigating dynamic GPS interferometric navigation to extend the capabilities of their fixed-wing airborne gravity measurement system, which is accurate to better than 3 mGal (3×10^{-5} m/s^2), to operation over land. In addition to providing the accurate positioning necessary for airborne gravimetry, GPS interferometric altimetry, in conjunction with radar altimeters, may be used in the future to study oceanographic phenomena and to obtain accurate ice profiles in glaciated parts of the world. The Connection Machine, an experimental facility that exploits the natural computational parallelism inherent in data-intensive research problems, has



NRL's facilities in support of acoustic investigations are located at the main Laboratory site in the Acoustic Division and in Orlando, Florida, at the Underwater Sound Reference Detachment (USRD). At the main Laboratory site, there are three research tank facilities—one instrumented for near-field acoustical holography, one for acoustic scattering measurements, and a third recently completed facility for the study of underwater structural acoustics. The latter is instrumented with state-of-the-art robotic controllers for acoustical scanning of large, irregularly shaped bodies.

been established for use by researchers both within and outside the Laboratory. The USRD facilities are described with NRL's field stations.

• Radar

NRL has gained worldwide renown as the "birthplace of radar" and has maintained its reputation as a leading center for radar-related research and development for a half century. An impressive array of facilities managed by NRL's Radar Division continues to contribute to this reputation. These include airborne and laboratory radar cross section measurement systems, an airborne APS-137 radar with ISAR image processing, and an airborne adaptive array laboratory. Also, the division manages and maintains a radar display test bed, an IFF ground station, a digital signal processing facility, and a radar cross section prediction facility. A radar research and development activity is located at the Chesapeake Bay Detachment (CBD), Randle Cliffs, Maryland. It has separate facilities for specific types of systems that range from high-frequency, over-the-horizon systems to millimeter wave radars. The SENRAD radar test bed, a flexible and versatile system for demonstrating new developments in radar, and a point defense radar test bed are also located at CBD.

• Information Technology

The Information Technology Division, which includes the Navy Center for Applied Research in Artificial Intelligence, is at the forefront of DoD research and development in telecommunication, computer science, and artificial intelligence. The division maintains a local area computer network to support its research.

The network comprises a Gould 9005 UNIX machine, Symbolics, LISP machines, SUN and

NRL scientists in the Human Computer Interaction Laboratory are investigating methods by which computer users can communicate commands to computers through eye movement, as demonstrated here

Apollo workstations, laser printers, network gateways, and terminal servers. A Butterfly 128-node parallel processor is also part of the division's computer resources. The network is connected to NRL's Central Computing Facility and to the MILNET, ARPANET, and other university networks. The network will become part of the Strategic Defense Initiative (SDI) Battle Management Technology validation facility.

• Electronic Warfare

The scope of research and development at NRL in the field of electronic warfare covers the entire electromagnetic spectrum, from basic technology research, component and subsystem development, to system design and effectiveness evaluation. Major emphasis is placed on providing the methods and means to counter enemy hostile actions in all battle phases, from the beginning—when enemy forces are mobilized for an attack—through the final engagement stages. For this purpose, NRL has constructed special research and development laboratories, anechoic chambers, and facilities for modeling and simulation. NRL has also added extensive new facilities where scientists can focus on the coordinated use of all organic defensive and offensive resources now present in the Fleet.

• Laboratory for the Structure of Matter

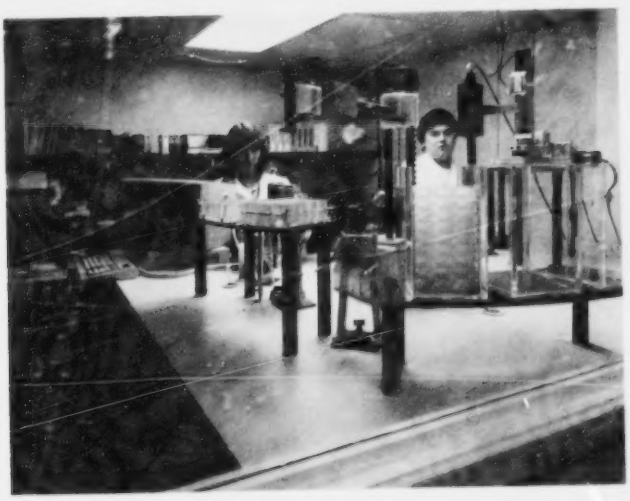
The Laboratory investigates the atomic arrangement of matter to improve old materials or to invent new materials. Various diffraction methodologies are used to make these investigations. Subjects of interest include the structural and functional aspects of energy conversion, ion transport, device materials, and physiologically active substances such as drugs, antibiotics, and antiviral agents. Theoretical chemistry calculations are used to complement the structural research. A real-time graphics system aids in modeling and molecular dynamics studies.

• Center for Bio/Molecular Science and Engineering

The Center for Bio/Molecular Science and Engineering conducts research in biotechnology aimed at solutions of Navy and Department of Defense problems. Long-term research directions focus on complex biomolecular systems and are aimed at gaining a fundamental understanding of the structures and functions of biologically derived systems. The staff of the Center is an interdisciplinary team performing basic and applied research in a number of diverse areas including biochemistry, biophysics, synthesis, and thin-film fabrication. Because of the interdisciplinary nature of this work, most of the research being performed in the Center is of a collaborative nature. The Center's associate concept is a key way of establishing this collaboration. Center associates come from other research areas within NRL as well as universities, industry, and other Government laboratories.

• Chemistry

NRL has been a major center for chemical research in support of Navy operational requirements since the late 1920s. The Chemistry Division continues its tradition with a broad spectrum of basic and applied research programs concerned with fuels and combustion, corrosion, advanced polymeric materials, ultrasensitive detection methods for chemical agents, and special



Shown is the automated protein crystal growth system developed by the Laboratory for the Structure of Matter to prepare large, single crystals of proteins for X-ray diffraction studies

Lipsome-encapsulated hemoglobin (LEH) is made for in vitro and in vivo studies in small animal models by NRL's Center for Bio/Molecular Science and Engineering

materials for electronic warfare applications. Modern facilities for research include a wide range of the most modern optical, magnetic, and ion-based spectroscopic devices, a 325-m^3 (11,400 ft^3) fire research chamber (Fire I), multiple facilities for materials synthesis and physical/chemical characterization, high- and low-temperature equipment, and extensive surface-analytical instrumentation. The division has recently developed the 475-ft ex-USS *Shadwell* (LSD-15) into an advanced fire research ship.

• Materials

NRL has capabilities for X-ray and electron diffraction analyses and for electron and Auger

spectroscopy. It has a secondary ion mass spectrometer for surface analysis that significantly extends the diagnostic capability of the technique. A high-resolution, reverse-geometry mass spectrometer is used to probe reactions between ions and molecules. The Laboratory has a fully equipped fatigue and fracture laboratory, a modern vacuum arc melting furnace for reactive metals, an ultrasonic gas atomization system for making metal powders, and hot isostatic press facilities. The Laboratory's cryogenic facilities include dilution refrigerators and superconducting magnetic sensors for measuring ultrasmall magnetic fields. Also available are two molecular beam epitaxy devices for growing thin films.

A new Epi-Center was recently dedicated at NRL for the epitaxial growth of magnetic and electronic materials. This is the first multichambered growth system devoted to combining magnetic and semiconducting integrated circuitry at NRL and the first at a DoD laboratory. The $1.4M facility is sponsored and funded jointly by the Materials Science and Technology Division and the Electronics Science and Technology Division.

• Optics

Ultralow-Loss, Fiber-Optic Waveguides—NRL has developed record-setting ultrahigh transparency infrared waveguides. These fluoride glass materials offer the promise of long-distance communications without the need of signal amplification or repeaters.

Focal Plane Evaluation Facility—This facility has extensive capabilities to measure the optical and electrical characteristics of infrared focal plane arrays being developed for advanced Navy sensors.

IR Missile-Seeker Evaluation Facility—This facility performs open-loop measurements of the susceptibilities of infrared tracking sensors to optical countermeasures.

Large Optic, High-Precision Tracker—NRL has developed a tracker system with an 80-cm primary mirror for atmospheric transmission and target signature measurements. By using a quadrant detector, the servo system has demonstrated a 12-mrad tracking accuracy. An optical correlation tracker system tracks objects without a beacon.

High-Energy Pulsed Hydrogen Fluoride, Deuterium Fluoride Laser—NRL has constructed a pair of pulsed chemical lasers each capable of producing up to 30 J of laser energy at 2.7 to 3.2 mm and 3.8 to 4.5 mm in a 2-ms pulse. This facility is used to investigate a variety of research areas including stimulated Brillouin scattering, optical phase conjugation, pulsed laser amplification, propagation, and beam combining.

Fiber-Optics Sensors—The development and fabrication of fiber-optic sensor concepts, including acoustic, magnetic, and rate-of-rotation sensors, are conducted in several facilities within the Laboratory's Optical Sciences and Acoustics Divisions. Equipment includes facilities for evaluating optical fiber coatings, fiber splicers, an acoustic test cell, a three-axis magnetic sensor test cell, a rate table, and various computers for concept analysis.

Digital Processing Facility—This facility is used to collect, process, analyze, and manipulate infrared data and imagery from several sources.

Emittance Measurements Facility—NRL routinely performs measurements of directional hemispherical reflectance from 2 to 16 mm in the infrared by using a diffuse gold integrating sphere and a Fourier Transform Spectrophotometer

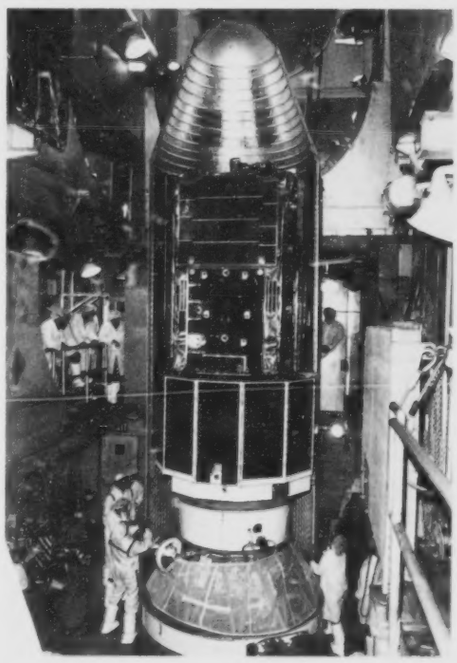
(FTS). Sample temperatures can be varied from room temperature to 250°C and incidence angles from 0° to 60°.

• Electronics Science

In addition to specific equipment and facilities to support individual scientific and technology programs in electronics and electronic-materials growth and analysis, NRL operates the Nanoelectronics Processing Facility that provides services to electronics programs throughout the Laboratory and to external organizations. This facility provides support for NRL programs that require microelectronics processing skills and equipment. The facility includes a nanowriter that can be used to fabricate nanoscale (80 Å) structures and, in general, supplies NRL programs with a range of items from discrete structures and devices to complete integrated circuits with very large scale integration (VLSI) complexity based on silicon metal oxide semiconductors (MOS) submicrometer technology.

• Naval Center for Space Technology

In its role as a center of excellence for space systems research, the Naval Center for Space Technology (NCST) designs, builds, analyzes, tests, and operates spacecraft, as well as identifies and conducts promising research to improve spacecraft and their support systems. NCST facilities that support this work include large and small anechoic radio frequency chambers, clean rooms, shock and vibration facilities, an acoustic reverberation chamber, large and small thermal/vacuum test chambers, and modal analysis test facilities. NCST has a facility for long-term testing of satellite clock time/frequency standards under thermal/vacuum conditions linked to the Naval Observatory; a 5-m optical bench laser laboratory; and a hologram research laboratory to conduct research in support of the development of space systems.



A satellite system designed and built by NRL to carry Strategic Defense Initiative Organization (SDIO)-sponsored experiments was launched on February 14, 1990. Shown here is the half-nose fairing being installed on the Delta II rocket that launched the Low-power Atmospheric Compensation Experiment (LACE) satellite.

• Center for Advanced Space Sensing

The Center for Advanced Space Sensing conducts a broad program in sensing applications at wavelengths from radio to optical. This program includes space experiments, radio, IR, and optical astronomy by using ground-based facilities operated by the Center of national facilities (such as the Very Large Array of the National Radio Astronomy Observatory), and relevant technology applications to remote sensing, precise tracking, navigation, and imaging. To accomplish these programs, the Center operates Maryland Point Observatory, which consists of 84- and 85-ft radio antennas, which are used primarily for Very Long Baseline Interferometry (VLBI) and background

A new technique has been developed to make holograms with diode lasers. Here a researcher places a holographic slide in a holder while another researcher observes the laser diode beam through an infrared viewer.

environmental emissions at radio wavelengths. For the processing of VLBI data, the Center is a partner in the Washington, DC, Correlator Facility. For actively illuminated objects at radio wavelengths, the Center has a SAR image processing facility consisting of high-density digital recorders, super minicomputers, and software to process images. The Center is also developing space-based sensor technology. The middle-atmosphere sounder is a limb-scanning microwave spectrometer designed to fly on the Space Shuttle. At optical wavelengths, an interferometer capable of precision measurements of the size and positions of celestial objects is operated on Mount Wilson, California. To satisfy the computing needs generated for image processing and other data processing needs, the Center has an Alliant VFX-40 visualization graphics supercomputer.

Research Support Facilities

• Technical Information Services

The Ruth H. Hooker Research Library and Technical Information Center contains more than one million items including current journals. Its collections can be searched by computer-based catalogs. The Library also provides interlibrary loans, on-line literature searches, access to CD ROM databases, loans of microcomputer software, and a full range of reference services, including assistance in selecting and using microcomputer software.

Publication services include writing, editing, composition, phototypesetting, and publications consultation. The primary focus is on using computer-assisted publication techniques to produce scientific and technical information containing complex artwork and equations.

The diversity of the research conducted at NRL requires a corresponding diversity of graphic support, such as technical and scientific illustrations, computer graphics, design services, photographic montages/composites, airbrushing/photographic retouching, calligraphy, display panels, and framing.

Photography services include motion picture, video, and still-camera coverage for data documentation both at NRL and in the field. A photographic laboratory offers custom processing and printing of black and white and color films. Video services include producing video reports of scientific and technical programs. A new video studio and editing facility with 3/4 in. and VHS editing equipment were recently dedicated.

Information specialists prepare written and visual materials for dissemination to the public for use at exhibitions, professional meetings and seminars, and for internal information.

The DICOMED computer graphics system produces high-resolution, high-quality color images on 35-mm slides, 8 in. × 10 in. viewgraphs, 16-mm movies, or microfiche. It is driven by tapes generated on many different computer systems. It also accepts MacIntosh files in PICT or Scrapbook format.

• Central Computing Facility

The Central Computing Facility (CCF) consists of a Cray X-MP/216 Class 6.5 supercomputer supported by five DEC/VAX 700/8000 front-end systems. The peak processing speed of the two-processor Cray supercomputer is 470 million-floating-point-operations-per-second (MFLOPS). It has 16 million (64-bit) words of static MOS memory in 32 interleaved

banks and three interconnected I/O processors with four million words of shared buffer memory.

The system is accessed by VAX minicomputers at the central computing site by local area networks at NRL, by the Internet (MILnet/DDN), and by SURAnet/NSFnet at remote sites. The CCF front-end system provides terminal access by direct line, dial-up, local area networks, or the Internet. It also provides database management, document processing, and graphics support. FORTRAN, PASCAL, and C are the primary programming languages for the Cray system. A wide range of scientific, statistical, and mathematical software is also available. MSC NASTRAN, NAG, IMSL, and ABAQUS are available on the Cray

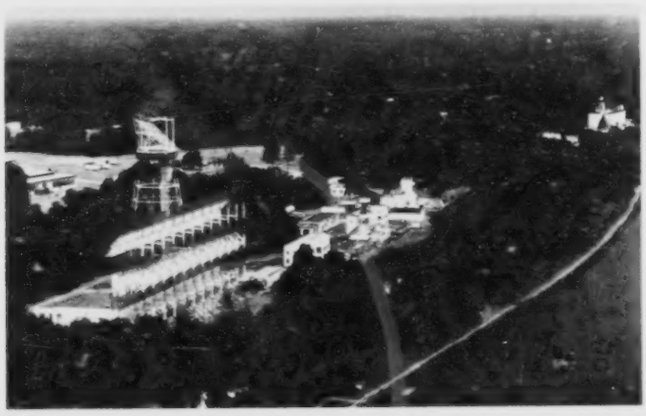
A complete range of graphics output devices is available including graphics terminals, laser printers, and plotters. Graphics software can also generate tapes for the DICOMED film-processing system located in TID. An IRIS 4D/GT graphics workstation with Matrix camera, color printer, and NTSC video output is available in the VISc lab at the Research Computation Division.

FIELD STATIONS

NRL has acquired or made arrangements over the years to use a number of field sites or auxiliary facilities for research that cannot be conducted in Washington, DC. They are located in Maryland, Virginia, California, Colorado, Alabama, and Florida. The two largest facilities are the Chesapeake Bay Detachment (CBD) and the Underwater Sound Reference Detachment (USRD).

- Chesapeake Bay Detachment (CBD)

CBD occupies a 168-acre site near Chesapeake Beach, Maryland, and provides facilities and support services for research in radar, electronic warfare, optical devices, materials, communications, and other subjects. Because of its location high above the Chesapeake Bay on the western shore, unique experiments can be performed in conjuntion with the Tilghman Island site 16 km across the bay from CBD. Some of these experiments include low clutter and generally low background radar measurements. By using CBD's support vessels, experiments are performed involving dispensing chaff over water and radar target characterizations of aircraft and ships. Basic research is also conducted in radar antenna properties, testing of radar remote sensing concepts, use of radar to sensor ocean waves, and laser propagation. CBD also hosts facilities of the Navy Technology Center for Safety and Survivability, which conducts fire research on simulated carrier, surface, and submarine platforms.



The Chesapeake Bay Detachment, located at Chesapeake Beach, Maryland

The Underwater Sound Reference Detachment, Orlando, Florida

• Underwater Sound Reference Detachment (USRD)

Located at Orlando, Florida, USRD functions as a link in the traceability of underwater sound measurements to the National Institute of Standards and Technology and also performs R&D for sonar transducers and related acoustic materials. Its semitropical climate and two clear, quiet lakes (the larger 11-m deep and nearly circular) are distinct assets to its research and development on sonar transducers and underwater reference standards and to its improvement of techniques to calibrate, test, and evaluate underwater acoustic devices. USRD has two large, high-pressure tanks for simulating ocean depths to approximately 700 m and 2100 m. Smaller pressure tanks simulate depths to approximately 7000 m. A spring-fed lake, located in a remote area about 40 miles north of USRD (the Leesburg Facility), provides a natural tank for water depths to 52 m with an ambient noise level 10 dB below that for sea state zero; larger objects can be calibrated here. A 15-cm shock tube simulates 60 pounds of high explosive at a range of 20 ft for shock testing small sonar transducers. The detachment provides acoustic equipment and calibration services not only to hundreds of Navy activities and their contractors but also to private firms and universities not engaged in DoD contracts.

• Marine Corrosion Test Facility

Located on Fleming Key at Key West, Florida, this facility offers an ocean-air environment and clear, unpolluted, flowing seawater for studies of environmental effects on materials. Equipment is available for experiments involving weathering, general corrosion, fouling, and electrochemical phenomena, as well as coatings, cathodic protection devices, and other means to combat environmental degradation.

• Flight Support Detachment (NRL FSD)

Located on the Patuxent River Naval Air Station at Lexington Park, Maryland, NRL's FSD provides facilities and service for airborne research. Four P-3 variant aircraft are maintained and operated by NRL and Detachment personnel.

The Marine Corrosion Facility, located at the Naval Air Station in Key West, Florida, has 1000 feet of seawall, 8000 square feet of laboratory and test areas, and an endless supply of natural seawater for evaluating ship systems and components

These airplanes annually log over 2000 hours of flying time on a wide variety of projects ranging from bathymetry and electronic countermeasure research to studies of radar signal reflections.

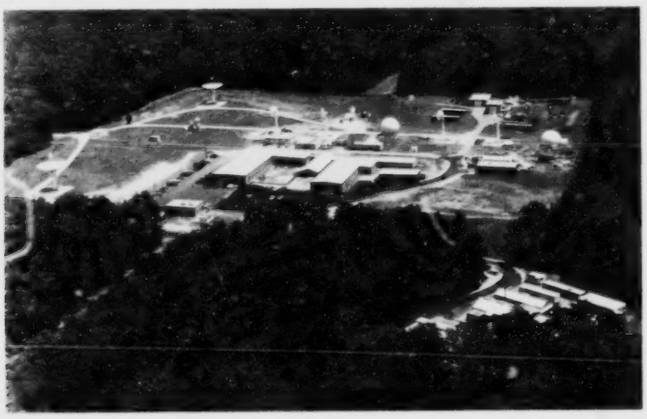
• Other Sites

Some field sites have been chosen primarily because they provide favorable conditions to operate specific antennas and electronic subsystems and are close to NRL's main site. Maryland Point, south of NRL, operates two radio telescopes (25.6 and 26 m in diameter) for radio astronomy research. NRL's Waldorf Facility, south of NRL, operates 18.3-m, X-band and S-band antennas for space and communications research. Pomonkey, a field site south of NRL, has a free-space antenna range to develop and test a variety of antennas. The antenna model measurement range in Brandywine, Maryland, has a 4.6-m diameter turntable in the center of a 305-m diameter ground plane for conducting measurements on scale-model shipboard and other antenna designs.

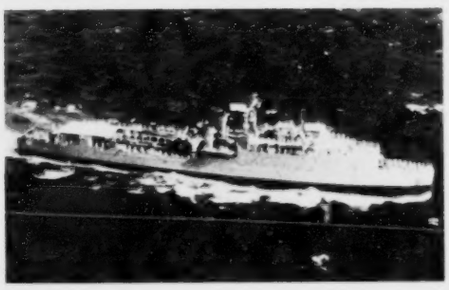
• Research Platforms

NRL uses ships and aircraft to conduct some of its research. Ocean-going research ships are obtained from a pool of vessels maintained by the Naval Oceanographic Office, Bay St. Louis, Mississippi.

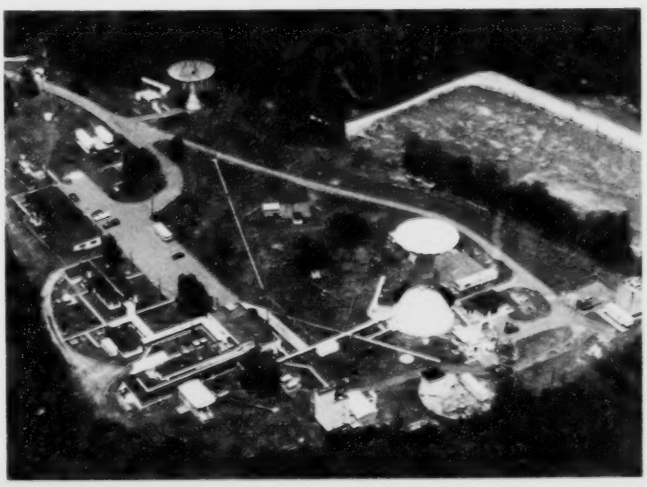
Scientists from NRL's Space Science Division and Woods Hole Oceanographic Institution (WHOI) are working together to conduct a series of air-sea interaction experiments by using airships. In these experiments, the scientists will make microwave scatterometer and oceanic surface-flux measurements from a manned airship to develop an improved, satellite-based, remote wind-sensing system.



The Blossom Point Satellite Tracking and Command Facility



The ex-USS *Shadwell* (LSD-15), now anchored in Mobile Bay, Alabama, serves as a fire test platform for the Navy's Systems Commands, under the control of NRL's Navy Technology Center for Safety and Survivability



The Microwave Space Research Facility

NRL in the Future

To continue its growth and provide preeminent research for tomorrow's Navy, NRL must maintain and upgrade its scientific and technological facilities at the forefront. Its physical plant to house these facilities must also be adequate. NRL recently embarked on a Corporate Facilities Investment Plan (CFIP) to renew its physical plant. This plan and future facility plans are described below.

THE CORPORATE FACILITIES INVESTMENT PLAN (CFIP)

The CFIP is a financial spending plan to provide modern research facilities at NRL by the year 2000. The plan calls for both Congressional and Laboratory investment and is updated and altered as changes occur in scientific emphasis and Congressional attitude. Over the past several years, Congressionally approved military construction (MILCON) funds were used to construct the new Electro-Optics laboratory and to complete the final phase of the Tactical Electronic Warfare facility. At this time, funds are being requested to build a second wing to the Electro-Optics Building and a facility to house the Naval Center for Space Technology.

In the past years, NRL general and administrative (G&A) funds were used to renovate Buildings 16, 32, 34, 35, 46, 47, 56, 58, and major portions of several other buildings. Approximately $4 million of Laboratory funding is budgeted for modernization each year.

- Center for Bio/Molecular Science and Engineering

The Center for Bio/Molecular Science & Engineering (BMSE) was established in October 1989 to conduct research on biomaterials and biotechnology of interest to the Navy. Work is now under way on the renovation of Building 12 to house this research effort. In Phase I, 5000 ft^2 in the basement of Building 12 are being renovated to contain a complete electron microscopy facility, including three electron microscopes and preparative work areas. Additional facilities will include a darkroom and laser laboratories. This work is scheduled for completion in FY 91. Major renovations on the remainder of the 35,000 ft^2 projected for FYs 93 and 94 will provide modern facilities for biotechnology research, such as sterile hoods, controlled temperature rooms, biochemistry and genetic engineering wet labs, and stringent clean rooms.

- Vacuum Ultraviolet Space Instrument Test Facility

The Space Science Division will soon install a new vacuum ultraviolet space instrument test facility. This facility will be capable of housing space instrumentation up to 2 m in diameter and 5 m in length. While exposed to high vacuum (10^{-7} torr), instruments can be illuminated by a simulated solar spectrum for alignment and verification tests. The facility will also include a 13-m evacuated extension containing sources to simulate the solar corona. An externally mounted 1-m diameter heliostat will be employed to project a beam from the sun directly into the vacuum chamber. In the near future, the facility will be used to test space instruments that are presently under development for flight on NASA's Orbiting Solar Laboratory spacecraft and European Space Agency's Solar and Heliospheric Observatory spacecraft. The facility will be fully operational in 1991.

- Optical Sciences

In FY 91, NRL will begin construction of the second phase of the Electro-Optics Research Laboratory (MILCON Project P-115). This will be a 50,000 ft^2 addition to the existing Bldg. 215 and will accommodate approximately 120 scientists and engineers and their research facilities. Completion and occupancy should occur in the last quarter of FY 93 or the first quarter of

FY 94. This facility will allow consolidation of the fiber optics and glass materials activities into one location and will replace obsolete and inadequate silica glass facilities in Bldg. 12 with new, state-of-the-art facilities. It will allow closer coordination between the infrared detector development activity and sensor system activities. Many computational sensor testing and modeling facilities will be contained in the new structure.

• Plasma Physics Facilities

A major, 2-kJ KrF-laser facility will be established in the Plasma Physics Division by the end of FY 93. This facility is being initiated to provide intense radiation for studying inertial confinement fusion target heating at short wavelengths. A new 3-MJ, 10-MA pulsed-power facility, ROOK, is being constructed for inductive energy storage research and should be ready in the FY 90-91 timeframe.

• Center for Materials Research

The Department of the Navy is in the process of programming construction of a special-purpose laboratory. This special facility will provide stringently clean laboratories with carefully controllable temperature, humidity, vibration isolation, ambient dust, and power for investigations in the rapidly evolving fields of electronic technology and nanometrics.

• Midway Research Center

NRL's newest field site, the Midway Research Center (MRC), is located on a 158-acre site in Stafford County, Virginia. Located adjacent to the Quantico Marine Corps Base, the MRC consists of a 5000 ft^2 operations/administration building and two of three programmed 60-ft diameter parabolic antennas housed in 100-ft radomes. When completed, the MRC, under the Navy Center for Space Technology, will provide NRL with a state-of-the-art facility dedicated solely to space communications and research.

• Electronics Science and Technology

In collaboration with the Materials Science and Technology Division, a new epitaxial materials center, the "Epi-Center," has been established. At the heart of the Epi-Center is an MBE system that consists of two linked chambers, one dedicated to narrow energy gap semiconductors and the other dedicated to large energy-gap semiconductors. Work on mixed narrow energy-gap, large energy-gap semiconductor systems can be carried out by transferring samples from the respective chambers.

Other important division emphases are the continual upgrading of the Nanoelectronics Processing Facility and expanding activities in the nanoelectronics physics program. A key feature of the latter is the comparison of lithography by means of a state-of-the-art E-beam machine with high electron energies and a scanning tunneling microscope (STM) with low electron energies.

• Fire Research Facility

Construction is under way at the Fire Research Facility at CBD to expand the current facilities. Once completed the facility will have a 50 × 50 × 50-ft burn building with an attached control center, three lab/office complexes of about 2500 ft^2 each, and a new, large, concrete minideck (to simulate air-capable ship decks) for expanded large-scale fire-fighting studies. FIRE-I, NRL's 325-m^3 (11,400-ft^3) pressurizable fire research chamber, has been relocated to this site.

• Radar Mode Test System

The Radar Division has acquired the Radar Mode Test System to evaluate the performance of NATO compliant Mark XV IFF radar mode (RM) equipment. It has been used to test equipment from the United Kingdom and will have application to the evaluation of NRL- and contractor-developed RM equipment

REHABILITATION OF SCIENTIFIC FACILITIES

Specialized facilities are being installed or upgraded in several of the research and support divisions.

• Chesapeake Bay Detachment

Three laboratory buildings at the Chesapeake Bay Detachment are scheduled to be renovated in FYs 91 and 92. The two-story buildings, which overlook the Chesapeake Bay, are between 8000 and 8600 ft^2. Plans call for an open lab/office design that can be readily adapted to suit the needs of the tenants. One building is currently unoccupied and will be available for use by any NRL division or other tenant when renovation is completed.

• Information Technology

An expanded computer/communication network is being implemented that will provide each researcher in the division with an office workstation (SUN, Apollo, or equivalent) connected to all the major scientific networks. Special test facilities are also being planned in support of specific R&D tasks. Facilities to support human-computer interaction research include an eye-monitoring system, touch screens and tablets, speech I/O hardware, high-resolution graphic displays, a 6-D tracker, a wall-sized display, and time-stamped video and audio recording equipment for monitoring experiments. An information security testbed is being planned to enable the interconnection of communication security and computer security devices to address network and system security problems.

• Plasma Physics

An inductive energy storage facility, PAWN, is being upgraded to increase the output power from 0.1 up to as much as 1.0 terawatt. This facility will be more than an order of magnitude more compact than similar generators when final development stages are completed. PAWN will be used for intense electron and ion beam generation research and in X-ray laser development. A low-frequency (300 MHz to 10 GHz), high-power microwave facility, which uses a relativistic klystron concept, is being upgraded to produce multigigawatt coherent radiation pulses. A new laser facility is also planned. It will use a powerful KrF laser and a target chamber to conduct inertial confinement fusion research.

• Radar

The Radar Division has installed a computer-aided engineering (CAE) facility to aid in digital system design. The system has seven full-color graphics workstations to provide capabilities for circuit design and simulation and printed circuit board layout. The facility has been used to design systems based on commercially available components as well as advanced systems incorporating VHSIC and gate array technologies. It has proven to be a valuable tool in evaluating new technologies for radar signal-processing requirements. The facility is currently being expanded to include three SUN workstations and ADAS software, which will allow designs to be modeled and simulated at the system level. Future plans call for acquiring VHDL (VHSIC Hardware Description Language) software for the workstations, which is supported by ADAS. This would provide designers with an integrated toolset to model and simulate their designs from the system level down to the device level.

• Acoustics-Target Research Tank

Tank facilities for acoustic target research in the Acoustics Division will be significantly expanded to extend the range of target sizes. The expanded model tank is planned to contain a water volume of approximately 30,000 m^3.

• Underwater Sound Reference

A new, precision measurement system (PMS) is being installed in each of four facilities—at the Lake Facility, the Leesburg Facility, and the two

large high-pressure tank facilities. PMS is a sophisticated, computer-controlled, signal-generation and data-acquisition system that provides significantly increased accuracy, dynamic range, and signal to noise than was previously available. It allows the use of new, sophisticated signal-processing techniques being developed for making lower frequency measurements on sonar transducers and related acoustical coating materials under reverberation-limited conditions, such as in the large, high-pressure tank facilities. PMS will also process acquired data very rapidly so that most results can be presented to customers at the time of the measurements.

• Materials Science and Technology

Renovation is proposed for Building 3, which is now made up of two of the original five buildings at NRL, to contain modern laboratories for studies of thin-film deposition and characterization, superconducting materials, magnetic materials, and other materials science projects. The new space will feature the most modern molecular beam epitaxy and other materials synthesis and processing equipment, an up-to-date fatigue and fracture laboratory and state-of-the-art diagnostic equipment, including electron microscopes, spectrometers, and electron and X-ray diffraction equipment. The renovated building will also contain office and laboratory space for approximately 70 technical personnel.

Further Information: The NRL *Fact Book* gives more details about the Laboratory and its operations. It lists major equipment, current fields of research, field sites, and outlying facilities. It also presents information about the responsibilities, organization, key personnel, and funding of the divisions, detachments, and other major organizational units.

Information on the research described in this *NRL Review* may be obtained by contacting Dr. Richard Rein, Head, Technology Transfer and Special Programs, Code 1003.1, (202) 767-3744. General information about NRL may be obtained from Information Services, Code 4810, (202) 767-2541. The sources of information on the various nonresearch programs at NRL are listed in the *NRL Review* chapter entitled "Programs for Professional Development."

HIGHLIGHTS OF NRL RESEARCH IN 1990

Retrieval of the LDEF/HIIS Experiment

NASA's Long Duration Exposure Facility (LDEF) was retrieved by the Space Shuttle in January 1990 after this nominal one-year mission spent almost six years in space. Aboard LDEF was NRL's Space Science Division's Heavy Ions in Space (HIIS) experiment, a cosmic ray detector designed to address questions important both to astrophysics and to understanding the radiation environment encountered by humans and hardware in space. HIIS has also returned new information on other hazards in the space environment. The multilayer insulation blankets and track detector stacks in HIIS are nearly ideal capture cells for micrometeoroids and space debris. LDEF's largest micrometeoroid impact was found in HIIS. It and numerous other impacts are now being studied by micrometeoroid and space debris experts at the Johnson Space Center. The thermal blankets on the HIIS experiment, well beyond their one year design lifetime, were damaged by UV radiation and atomic oxygen and were partially detached from the spacecraft. These blankets will be studied by spacecraft engineers to investigate the effects of the space environment on them.

***

Development of New Sensors and Techniques for Remote Sensing of Space Weather from Operational Satellites

A Space Science Division's basic research program of upper-atmospheric physics and ultraviolet remote sensing has led to the development of new techniques for optical remote sensing of neutral atmospheric and ionospheric densities from space. New ultraviolet sensors have been developed to measure limb profiles of atmospheric airglow, and new algorithms have been generated to convert these measurements into neutral and electron density profiles. The Defense Meteorological Satellite Program has adopted these new techniques in the form of an operational sensor system called the Special Sensor Ultraviolet Limb Imager (SSULI) for inclusion on its Block 5D3 operational weather satellites. The sensors are derived from ultraviolet instruments developed for the Remote Atmospheric and Ionospheric Detection System (RAIDS) and an NRL proof-concept satellite experiment.

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Progress in the Development of the NRL Modified Betatron Accelerator

The trapped current and the beam energy in the Plasma Physics Division's modified betatron accelerator have substantially increased during FY 90. Specifically, the trapped current increased from 0.5 kA to 1.5 kA and the beam energy from 12 MeV to 18 MeV. The 1.5 kA current exceeds by 50% the design specification of the device, while the energy is only 10% below the initial specification. The modified betatron accelerator has the potential to lead to a compact, lightweight, high-current device that is suitable for shipboard installation. Net technical assessment studies show that the modified betatron is the lightest and most compact among all the high-current accelerators considered. The modified betatron has

been under development at NRL since 1980. After the successful completion of its construction and testing of the various power subsystems, the device entered its initial phase of operation that includes beam injection and capture and electron ring recirculation. These experiments have provided valuable information on several critical physics issues associated with the high current, toroidal accelerators.

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Stable Propagation of a High-Current Charged-Particle Beam

A national program studying the feasibility of using a charged-particle beam (CPB) as a directed-energy weapon (DEW) has been in progress for nearly 20 years. This program has been funded by the Defense Advanced Research Projects Agency, the Office of Naval Research, and carried out by NRL's Plasma Physics Division. The research program has three primary goals that would demonstrate feasibility and provide the necessary building blocks for producing a CPB DEW sometime early in the next century. The goals are to prove that a beam can propagate stably in the atmosphere over a significant range, to demonstrate that it is possible to extend the range of such a beam to significant distance, and to develop the technology necessary for a compact, high-energy accelerator. NRL performs experimental and theoretical research in all three areas. A new propagation laboratory, constructed with NRL capital equipment funds, was completed in 1988. Since then this laboratory has been bringing the accelerators and numerous diagnostics on line and performing preliminary experiments aimed at both propagation stability and range extension.

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Real-Time Adaptive Monopulse Countermeasures (CM)

The Advanced Technology Demonstration (ATD) Program in the Tactical Electronic Warfare Division involves the application of two electronic warfare (EW) technologies designed to counter modern monopulse type, RF-guided antiship missile. The concept involves the use of an on board angle-deception ECM combined with real-time adaptive control and monitoring of the jammer's effectiveness to optimize the ECM's performance against the monopulse threat. The ATD consists of the marriage of two advanced technologies to improve softkill self-defense of a surface ship. The first technology provides an advanced, high-power angle deception capability against monopulse missile seekers. The second technology provides a real-time softkill effectiveness monitoring capability for assessing the effectiveness of ECM. The combination of these two technologies provides greatly improved ship survivability while optimizing the use of shipboard ECM against missile attacks.

***

Biosensor for Cocaine Detection

An antibody-based sensor has been constructed by the Center for Bio/Molecular Science and Engineering for detecting drugs of abuse. The sensor is configured to analyze hundreds of discrete samples rapidly or to be integrated with a continuously operating sample. Antibodies can recognize a drug molecule among millions of other molecules. We have chemically attached these naturally selective antibodies to a solid support, bound-fluorescent cocaine to the active site and introduce a fluid stream. When samples that contain cocaine are introduced into the stream, the free cocaine displaces the fluorescent cocaine that is measured further downstream. This biosensor is faster, less expensive, and as sensitive as any method currently available for cocaine detection. It can be operated by personnel who lack scientific training and can be used outside a laboratory environment.

***

Turbine Blade Rejuvenation

A significant factor in the cost of operating and maintaining aircraft gas turbine engines is the frequent replacement of high-temperature turbine blades that have failed or reached some design limit or life. The Materials Science and Technology Division developed suitable rejuvenation and repair procedures for these blades to save the Navy and the other services several millions of dollars per year. Based on detailed understanding of the failure processes in these blade alloys, interrelation among the microstructure, load, temperature, and environment, NRL has developed methods to rejuvenate or repair these blades so that they can be made to last longer.

***

First Test of Fiber-Optic Hydrophones in the Arctic

In April 1990, two fiber-optic hydrophones measured the ambient acoustic noise under shore-fast ice at the mouth of Independence Fjord, in the vicinity of Kap Eiler Rasmussen, Greenland. Measurements were made by the Optical Sciences Division over a 12-day period and contained data ranging from more than 20 dB below sea-state zero (between 200 and 1000 Hz) to high noise levels caused by the presence of machinery. Noise measurements were made over a 0.03 Hz to 3 kHz frequency range. Several mechanical and operational requirements necessary for future Arctic use of fiber-optic hydrophones were demonstrated. First, the fiber-optic hydrophones and single-mode, fiber-optic cable showed that they are deployable and operational at temperatures between −20° and −40°C. Second, the lasers and electronic systems used to interrogate the fiber-optic hydrophones demonstrated that they could operate at the low noise levels required for high sensitivity in the fluctuating thermal environment of the shelters (tents). Finally, the hydrophone sensitivity and dynamic range were demonstrated to be adequate for future Arctic applications.

***

Launch and Operation of the Low-Power Atmospheric Compensation Experiment (LACE) Satellite

NRL's Naval Center for Space Technology (Space Systems Development Department) was tasked in 1935 to design, integrate, test, launch, and operate a satellite to serve as an instrumented target for low power, ground-based lasers to conduct atmospheric compensation tests. In 1987, tasking was expanded to include acquisition, testing, integration, and operation of an instrument that obtains images of the ultraviolet emission from rocket plumes. Launch of the LACE satellite occurred on 14 February 1990. Data from the LACE satellite's sensor array subsystem will be used in support of atmospheric compensation programs of the Strategic Defense Initiative Organization.

***

Large-Scale, High-Energy Laser Windows from Heavy-Metal-Fluoride Glass

Significant progress has been made by the Optical Sciences Division in the development of large windows from heavy-metal-fluoride (HMF) glasses for high-energy laser (HEL) transmission. These glasses have a theoretical absorption loss minimum of less than 2×10^{-7} cm^{-1} at 2.5 μm and practical losses of less than 5×10^{-4} cm^{-1} between 1 and 5 μm. In addition, HMF glasses exhibit near zero optical-path

distortion when heated by laser fluences. Until 1988, problems associated with the crystallization of these glasses limited the size of windows made from HMF glasses to disks less than 1 cm in thickness and 4 cm in diameter. However, new glass compositions and innovate processing have made the production of much larger windows possible. In FY 90, a 45-kg window, 4 cm in thickness and 60 cm in diameter, was produced. The ability to cast windows of this size makes HMF glasses the best material for high-energy, mid-IR optical components.

***

Effects of Gravity on Flames in Premixed Gases

Differences in the shape and dynamics of flames propagating upward and downward in tubes have been experimentally observed for many decades. Flames propagating in many premixed fuel-air mixtures are prone to various kinds of instabilities. In general, these instabilities result in the flame having a complex, multidimensional structure that also varies in time. Now these flames have been numerically simulated by the Laboratory for Computational Physics and Fluid Dynamics. The simulations provide a better understanding of the interplay among various mechanisms that are responsible for the observed behavior of these flames. Understanding the behavior of flames under reduced and varying gravity situations is crucial for the safe and efficient operation of space systems such as the Space Shuttle and the proposed Space Station.

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Magnetohydrodynamic Computational Models

Numerical modeling has played an important role in gaining a greater understanding of the phenomena occurring in the solar chromosphere. An important but not yet fully understood problem is the mechanism that heats the solar chromosphere and the effects of the solar magnetic field on this heating. A new, three-dimensional magnetohydrodynamic code has been developed that for the first time permits accurate modeling of the dynamics of solar arcades. Scientists in the Laboratory for Computational Physics and Fluid Dynamics have developed a new three-dimensional, semi-implicit, Fourier pseudospectral-Chebyshev collocation magnetohydrodynamics code for use in numerical studies of coronal heating. A code of this type will allow a greater understanding of the mechanisms that produce heating in the solar coronal that can lead to such phenomena as solar flares.

***

Defect Studies in Semi- and Superconductors

The effect of radiation on the electrical properties of semiconductors (such as silicon, germanium, and gallium arsenide, and the recently discovered high-temperature superconductors) have been found to be directly proportional to the displacement energy (nonionizing energy loss) deposited by the incident particle. This means that once an effect has been measured for one kind of incident particle, a prediction can be made for any other particle of any energy. The scientists in the Condensed Matter and Radiation Sciences Division report that this predictive power is useful in applications including SDI and the NRL/High Temperature Superconducting Space Experiment.

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Theory of Intermetallic Alloys

The density functional theory (DFT) within the local density approximation points the way toward first principles evaluations of a variety of electronic and mechanical properties in solids. The DFT has been

implemented by using the tools of band-structure methods to determine the equation of state for many materials. Researchers in the Condensed Matter and Radiation Sciences Division have applied the linearized, augmented plane-wave method to calculate the zero-temperature equation of state and the elastic moduli for the following intermetallic compounds: SbY, CoAl, RuZr, NbIr, RuAl, NiAl, and Ni_3Al. The calculated lattice constants and bulk moduli are within 2% and 7% of the experimental values, respectively. In addition, all the elastic constants were calculated and compared with the experiment, where available, with similar 5% to 10% agreement. The predictive capability of these calculations can show experimentalists which intermetallic alloys are the best candidates for exploration as light-weight, high-strength, and high-melting-temperature materials.

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Digital Sidelobe Canceler Technology Transfer

Shipboard radars are vulnerable to electromagnetic interference (jamming) that enters system receivers through antenna sidelobes. The Radar Division's efforts in exploratory development have developed the technology to provide a considerable increase in sidelobe-canceler performance. Having developed the technology for an improved shipboard sidelobe canceler, consideration was given to adapting this technology to active Fleet systems. The results of this program will significantly improve the performance of this radar in a jamming environment.

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Unified Network Technology/Advanced Technology Demonstration (UNT/ATD)

Under UNT/ATD, a distributed control, self-organizing, adaptive networking architectural concept called the linked cluster architecture (LCA), has been developed for application to tactical-warfare-stressed scenarios. Accomplishments by the Information Technology Division during FY 90 include both software and hardware development of network and link controllers, performance simulations of the network, system integration and testing, and a seven-node hardware demonstration (involving a ship, an aircraft, and five land-based nodes) of the networking architecture. UNT/ATD's primary objective is to demonstrate the operational benefits of new network technology and its impact on naval communication services. The Linked Cluster Architecture (LCA) network design was developed and applied to a Naval Intrabattle Group (IBG) communication system. The LCA network allows for reconfiguration of communication links under dynamic conditions, improved timeliness and information throughput, and enhanced survivability (since it is not dependent on centralized control).

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Eye Movement-based Interaction Techniques for Human-Computer Communication

In seeking previously unused methods by which users and computers can communicate in time-critical situations, the Information Technology Division has investigated the usefulness of eye movements as a fast and convenient auxiliary user-to-computer communication mode. The barrier to exploiting this medium has not been eye-tracking technology but the study of interaction techniques that incorporate eye movements into the user-computer dialogue in a natural and unobtrusive way. A set of generic user-computer interaction techniques for the use of eye movements in a real-time, user-computer dialogue has been developed. The eye-movement-based-interaction techniques will provide a rapid, user-to-computer communication channel for time-critical applications such as command and control. A faster, more natural interface incorporating eye movements can make computer use faster and more

convenient for many types of users and can enable a commander to speed up information-gathering and decision-making processes during a crisis.

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Full-Engagement Decoy Simulator (FEDS) Visualization

Within the last two years, the Effectiveness of Navy Electronic Warfare Systems (ENEWS) Program of the Tactical Electronic Warfare Division has enhanced the visualization capability of the FEDS through the development of a highly flexible display presentation package of the simulation results. The features are selectable by the user to emphasize the particular characters of the engagement that the simulation highlighted. The entire set of missiles or an individual missile can be displayed; the gates for individual missiles or the scanning characteristics of individual emitters can be selected to show detailed results of the simulation. This program can be used both to verify results from other evaluation techniques (such as laboratory and field simulators) and to show the correspondence of FEDS results with those techniques. The relative cheapness of digital simulation, when coupled with a clean presentation of understandable results, makes FEDS simulation an even more valuable asset.

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Low-Altitude/Airspeed Unmanned Research Aircraft (LAURA)

The Tactical Electronic Warfare Division's LAURA Program has demonstrated the capability of small, remotely piloted air vehicles to fly efficiently at the shiplike speeds needed for electronic warfare (EW) missions. Three of the four aircraft developed in the LAURA Program were successfully flight tested. Test results show that the majority of the design goals were met and that long endurance flight at low airspeeds can be achieved for tactical, autonomous, and remotely piloted unmanned air vehicles (UAVs). The LAURA Program uses research results to demonstrate the practical application of those technologies and proves the feasibility of developing long-endurance, low-speed, tactical-electronic decoy vehicles.

***

MMIC/EW Receiver

With the general development of MMIC RF circuits, it became increasingly apparent that an assembly of these circuits could become the basis of an EW receiver. Thus, MMIC circuits (such as RF broadband low-noise amplifiers (LNAs), mixers, switches, and filters) became the basis from which the Tactical Electronic Warfare Division completed the design and fabrication of an MMIC/EW receiver. This receiver represents a significant improvement in the performance, weight, size, power, and cost of EW receivers through the use of MMIC technology. The availability of the MMIC/EW receiver will revolutionize the application of EW against modern threat emitters by permitting the use of many low-cost, high-performance EW receivers in a single, low-cost EW system.

***

Materials for Towed-Array Hose Walls

Polymeric materials currently considered for use in the TB-23, small-diameter, towed-array hose either do not possess the necessary aging and weathering resistance or satisfactory self-noise performance as a function of temperature. Changes in self-noise performance as a result of fill-fluid permeation and subsequent chemical reaction also often occur. The objective of this work performed by the Underwater

Sound Reference Detachment was to develop an elastomeric material that would exhibit the proper combination of extensional stiffness (Young's modulus) and internal loss, tensile properties, ozone and weather resistance, resistance to swelling and permeation by seawater and fill fluids, adhesion to reinforcing members, and ease of manufacture, for fabrication and evaluation as a reinforced, small-diameter hose wall for Navy use. This accomplishment may allow the Navy to use one type of material for several different types of arrays.

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Chemical Indicator for Hydrazine Detection: Active and Passive Dosimeter Systems

Hydrazine, monomethylhydrazine (MMH), and unsymmetrical dimethlydrazine (UDMH) are currently being used by DoD and NASA as hypergolic fuels. These hydrazines impose health hazards to personnel who come in contact with them; they are considered potential carcinogens. The threshold limit values (TLV) for exposure to these vapors are established at 100, 200, and 500 ppb respectively, and the exposure limits may be lowered to 10 ppb for all three hydrazines. To minimize the risk to employees, routine monitoring of personnel and their work environments is mandated. While instruments are commercially available to monitor the current TLV, none exists that is capable of monitoring the proposed TLV concentrations. The Chemistry Division has developed a colorimetric dosimeter system that can be used actively or passively to sample ambient air to detect hydrazine and monomethylhydrazine (MMH) at subpart-per-billion (ppb) levels. Acidified vanillin provides a real-time, low-cost indication of the proposed TLV levels of hydrazine and MMH in air. A patent was issued for the colorimetric indicator in February 1990. This technology provides rapid spot checks of the environment or can be adapted into a paper-tape instrument for continuous real-time detection.

***

Halon 1301 Test Gas Simulant

Halon 1301 is used by the Navy as a total-flooding, fire-suppression agent for protecting shipboard machinery spaces. However, Halon 1301 has been identified as contributing to the depletion of the Earth's stratospheric ozone; therefore production has been limited to 1986 levels by the Montreal Protocol. At present, all new and retrofit installations of Halon 1301 total-flooding fire protection systems in U.S. Navy shipboard machinery spaces require an acceptance discharge test. The primary reason for this testing is to verify the system design and performance. Discharge testing accounts for 60% to 70% of the Navy's total usage of Halon 1301. In view of the potential contribution of Halon 1301 to the stratospheric ozone depletion problem, the Navy has an urgent need to develop a simulant for Halon 1301 that would permit discharge testing to be conducted without polluting the atmosphere. After evaluating over 50 possibilities, sulphur hexafluoride SF_6 was found to be an ideal simulant for Halon 1301 for discharge testing. Not only does SF_6 have chemical and physical properties similar to Halon 1301, it is a nontoxic, inert, stable, nonflammable, odorless, and colorless gas. Extensive laboratory tests by the Chemistry Division and full-scale tests on the USS *Chancellorsville* (CG-62) verified the performance of SF_6. The simulant will be used in place of Halon 1301 for all new and retrofit installations of Halon 1301 total-flooding fire-protection systems in Navy shipboard machinery spaces during acceptance discharge tests.

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Sludge-Preventing Additives for Navy Diesel Fuel

Antioxidant additives to prevent sludge formation of diesel fuels used by the Navy for shipboard mobility are currently not allowed or approved for use. To rectify this situation and to prepare for the

possible use of such additives, NRL served as the lead laboratory in evaluating nine additives from commercial sources. Two of the nine additives evaluated by the Chemistry Division have been shown to possess superior sludge preventing properties. The use of these additives could reduce problems associated with sludge formation in fuels by one half. This will greatly impact the logistics of interrupted fuel movements, which can negatively impact combat readiness. Additionally, the consequences of sludge formation can critically impact ship mobility during combat operations. The cost-per-year to empty, clean, and inspect a one-million-barrel storate depot is about $3 million. The use of these additives will thus save the Navy about $1.5 million per depot per year in 1990 dollars.

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Deposition of Aligned, High-Quality, Potassium Tantalum Niobate (KTN) Films

KTN has very high electro-optic as well as pyroelectric coefficients. Its Curie temperature can be changed easily, and interesting devices have been made out of KTN bulk single crystals. This makes it attractive to attempt film deposition. Sol gel techniques were used to deposit very-large-area, flaw-free films having a range of tantalum-niobium ratios. A very high degree of crystallographic orientation was observed by scientists from the Materials Science and Technology Division on 111 Silicon and on SiO_2 substrates after 550° heat treatments. The attainment of flaw-free, large-area films is a significant accomplishment and the attainment of crystallographic alignment of these (in particular on silicon and SiO_2) is a major breakthrough. The deposition of electro-optic or pyroelectric films on single-crystal silicon allows the direct integration of electro-optic light modulators on a silicon chip. This increases as speed, reduces size, and provides related device advantages. Pyroelectric arrays integrated on a chip can lead to very small pyroelectric image analyzers.

***

Using Chaos to Drive Stable Systems

Over the last 15 years, the entire scientific community has become aware that another kind of motion exists beyond the usual equilibrium, steady-state, or cyclic (periodic) states known for centuries. That motion has come to be called chaos and appears in many guises in almost every scientific field. Although apparently random in nature, chaotic signals have been shown to be useful and more controllable than thought. Two independent applications that use chaotic signals as inputs were recently found by researchers in the Materials Science and Technology Division. One is the development of techniques to create synchronized but simultaneously chaotic systems. The other is the use of certain chaotic systems as replacements for periodic (cyclic) signals to prevent phase drift yet retain much of the desired behavior of the driven system. The synchronization allows systems to behave in ways that are difficult to predict (as is the nature of chaos) yet to remain acutely coordinated with each other. The chaotic "periodic" driving makes it possible to design complex, nonlinear systems and have behavior similar to simple periodic driving, yet no subelements of the system will get out of phase with any others. It also offers a plausible explanation of why so many chaotic signals are found in physiological systems, like the human body.

***

A New Technique for Controlling the Characteristics of Thin Magnetic Films

Magnetic materials in thin-film form have very important technological applications in magnetic recording, both as media materials and magnetoresistive read heads, as well as potential integrated microwave circuit elements. In almost all of these uses, it is very important to be able to control the

magnetization, anisotropy, and domain structure of the films. Scientists in the Materials Science and Technology Division demonstrated that the dipolar forces tending to keep the moment of magnetic thin films in the plane of the film can be dramatically enhanced by using multilayer films where adjacent layers are strongly coupled antiferromagnetically. By using materials in which materials in each of the layers is completely isotropic, an enhancement of dipolar anisotropy of more than a factor of four has been observed. Also observed is a unique "spin flop" transition, where as a function of applied magnetic field, the spins in each of the layers make a sudden transition from directions parallel and antiparallel to the applied field to directions almost perpendicular to the field. These effects have been explained theoretically and can be used as a unique and valuable tool for basic studies of fundamental interactions in magnetic materials and their interfaces. They have potential application in various kinds of thin-film magnetic devices, such as in magnetic-recording and random-access magnetic memory elements and in fundamental studies of such characteristics as interface exchange interactions and novel magnetotransport phenomena.

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Flashlamp-Pumped, Solid-State Laser for Medical Applications

Researchers in the Optical Sciences Division have developed a novel, high-efficiency, flashlamp-pumped, room-temperature, solid-state laser that produces optical pulses at a wavelength of 2.014 μm. The laser material is yttrium aluminum garnet (YAG) doped with small concentrations of CR^{3+} (0.6%) and Tm^{3+} (6%). The output wavelength corresponds to a transition of the Tm^{3+} ion, and the Cr^{3+} acts as a sensitizer to permit efficient pumping by an ordinary flashlamp. Output pulse energies ranging from a few millijoules up to several joules have been produced with efficiencies on the order of 4%. The significance of this new laser wavelength for medical applications derives from two factors: infrared radiation at 2.014 μm is readily transmitted by silica-cased optical fibers, and it is in a region of high absorption (water band) in biological tissue. In the near infrared wavelength region, laser ablation is most effective at wavelengths around 2 and 3 μm, which correspond to tissue absorption peaks. With regard to transmission, flexibility, durability, and nontoxicity, silica-based optical fibers have been demonstrated to be the delivery system of choice; their transmission window covers the spectral region between 0.3 and 2.3 μm. The new 2.01 μm laser is ideally suited for such procedures as laser angioplasty, arthroscopic surgery, and repair of herniated lumbar discs. Effectiveness of this laser for ablation of various types of tissue is currently being investigated.

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Fabrication of Bond and Etch-Back Silicon on Insulator (SOI) by Using a Strained $Si_{0.7}Ge_{0.3}$ Layer as an Etch Stop

Bond and etch-back SOI that uses a strained $Si_{0.7}Ge_{0.3}$ layer has been produced with a silicon thickness of 200 nm by molecular-beam epitaxy (MBE) by the Electronics Science and Technology Division. The material was measured to have a doping level of less than 10^{15} cm^{-3}, which is the residual dopant level of the MBE system. The utility of this material is that it enables good control of the fabrication process resulting in undoped, defect-free SOI. The etch-stop layer is epitaxially grown by using an electrically active element. The resulting material can be used to fabricate fully depleted (0.25-μm channel length) and complementary devices without needing compensation for residual dopant. This material is highly relevant to DoD applications and can be used in satellites or other high-speed equipment that is sensitive to radiation environments. The production of fully depleted devices enables ultrahigh speeds to be obtained. The use of bonded wafers gives the capability of radiation hardening the back channel of the devices, an important

criterion in fully depleted structures. The use of germanium over boron as the etch stop improves the performance of the material because of fewer defects and lower residual doping following fabrication.

***

Linear Theory of Field-Emitter-Array (FEA) Distributed Amplifier

A small signal theory of a continuously distributed FEA amplifier has been developed by the Electronics Science and Technology Division to calculate the gain and bandwidth of the amplifier. The dependence of the linear gain on beam energy, beam current, transmission line parameters, and the emitter performance characteristics is derived to determine the conditions for large amplification. Calculations show that a high gain of 3 dB/cm to 7 dB/cm in the frequency range 20 to 100 GHz with bandwidth in excess of 60% is feasible in this device. The theoretical work has led to a better understanding of the physical processes of the interaction in FEA-distributed amplifiers.

***

High-Resolution Lithography in a Polydiacetylene Negative Resist with a 50 kV E-Beam and a Vacuum Scanning Tunneling Microscope (STM)

A polydiacetylene negative resist developed by the Electronics Science and Technology Division demonstrates very high lithographic resolution when exposed with a 50 kV E-beam or a 5- to 10-V probe in a vacuum STM. A study combining the two lithographic tools addresses the fundamental limitations on the resolution of the resist. The low-voltage probe can both modify the resist topographically and image the resist films in situ. Examination of the latent image in the underdeveloped resist enables the exposure step to be studied independently of postexposure processing. The combined use of the 50 kV E-beam and the STM in a complementary set of experiments is a powerful approach to lithographic research. The STM has been demonstrated as a potentially viable lithographic tool. The results indicate that chemical modifications can improve the ultimate resolution of the resist.

***

MMW Radiometric Background Measurements

Thirty-seven GHz passive microwave measurements of terrain backgrounds were made by the Space Systems Technology Department of winter scenes near Grayling, Michigan, and of desert scenes near Yuma, Arizona. Infrared and 35 GHz radar measurements were made during the same period of time and from the same observation platform, providing simultaneous characterization of the test areas at both IR and microwave. Extensive meteorological measurements were made that supplied excellent ground truth for the experiments. Raster scans of the scenes were performed by using a dual, linearly polarized, Dicke-switched 37 GHz radiometer with a 1° beamwidth. The data were sampled every 0.5° in both elevation and azimuth. Measurements were made from an observation tower looking down on the background scene. Elevation depression angles varied from 10° to 60°, as measured with respect to the horizontal. Measurements of the downwelling sky radiation were also made so that emissivities of the background scene can be calculated. The ability of a sensor to detect and acquire a target depends, among other things, on the presence of clutter or "targetlike" objects in the scene. This study provides a terrain database that may be used to assist in evaluating the clutter level of test sites that are thought to be similar to areas of importance for military operations.

MEET THE SCIENTISTS

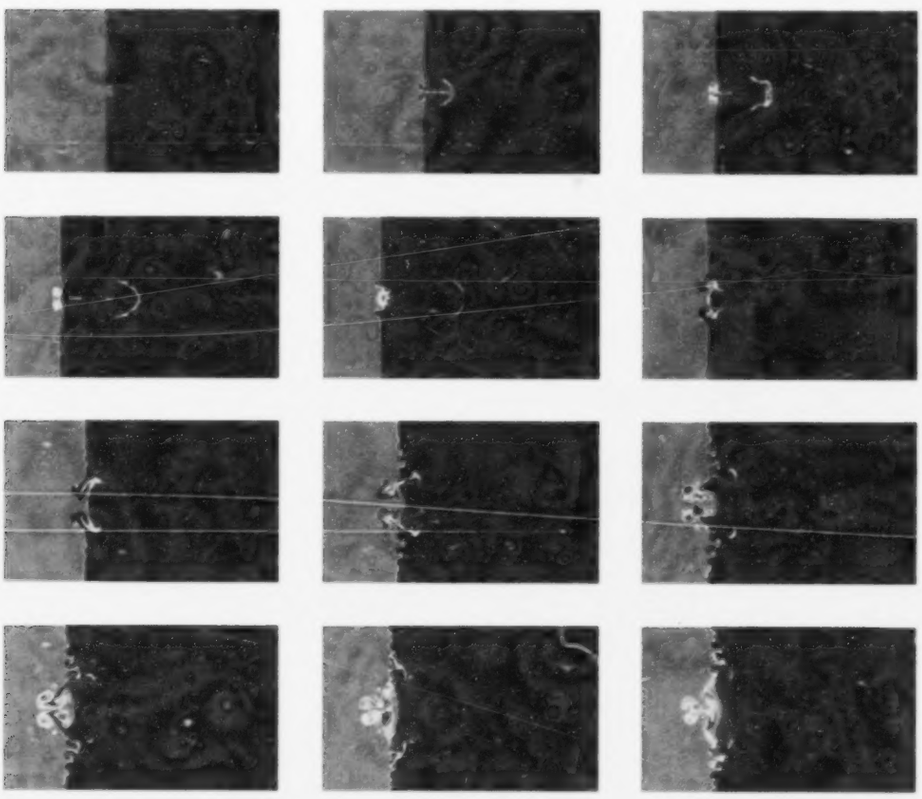
Dr. Herbert Gursky, superintendent of the Space Science Division, heads a highly successful effort of astronomy and atmospheric science. Division scientists have responsibility for major NASA– and DoD–sponsored experiments in the areas of solar physics, gamma ray astronomy and the higher portions of the atmosphere, including the analysis of space data and the modeling of the observed phenomena. Dr. Gursky is a pioneer in the observation of X rays from astronomical objects in space.

Dr. Frances S. Ligler, deputy head of the Center for Bio/Molecular Science and Engineering, leads NRL's interdisciplinary programs in biosensor technology. These programs are targeted toward the ultrasensitive detection of chemicals and pathogens in applications such as drug interdiction, aircraft safety, and defense against biological warfare agents. She and her group have initiated industrial negotiations for pertinent technology transfer to an industrial effort that plans clinical trials by 1994. This is patterned on their successful transfer of the NRL research on an artificial red blood cell, liposome encapsulated hemoglobin. "I am most proud of those aspects of our research that have direct application to the health and safety of Naval personnel and the general public."

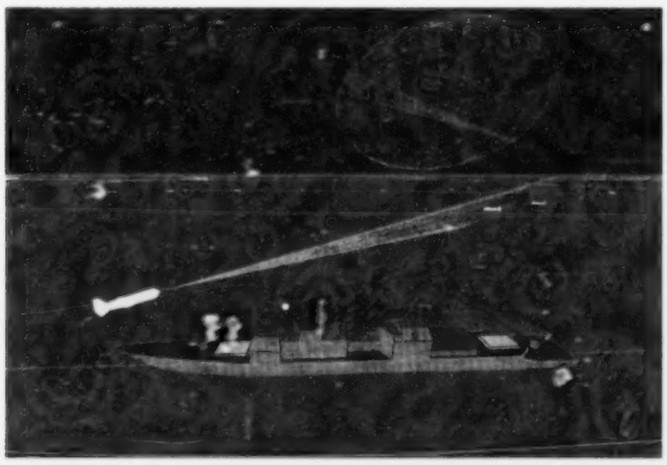
Dr. Robert W. Timme is the associate superintendent and civilian executive officer of the Underwater Sound Reference Detachment in Orlando, Florida. Prior to this assignment, he was head of the Transducer Branch and manager of the Navy's Sonar Transducer Reliability Improvement Program. Dr. Timme is involved with solving the problems of today's Fleet sonar and with developing new concepts to meet future Fleet requirements. He finds his job most satisfying because "it provides me the opportunity to make clear and tangible contributions toward solving the Navy's present and future problems. These contributions had their beginnings in NRL's research programs." Dr. Timme is a Fellow in the Acoustical Society of America, a three–time winner of the Alan Berman Research Publication Award, and has been presented the Superior Civilian Service Award.

COLOR PRESENTATION

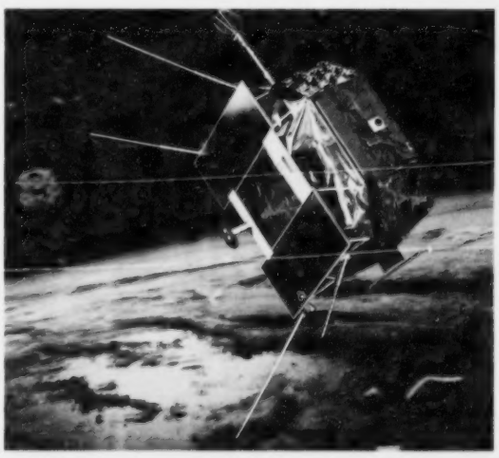
For visual interest, we present here some of NRL's latest scientific achievements and state-of-the-art equipment.



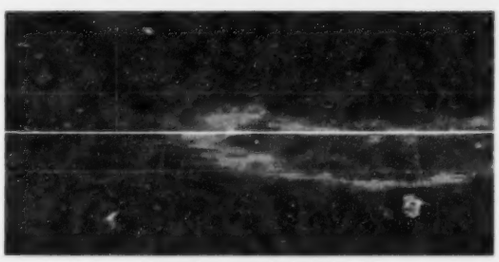
The hydrogen mass-fraction from numerical simulations of the evolution of interface structures between hydrogen and air generated by the Rayleigh-Taylor instability caused by the expansion waves is shown. Interface instabilities between fuel and air flows could be used to enhance the mixing and, therefore, increase the combustion efficiency in air-breathing engines. (C. Li, Code 4410)



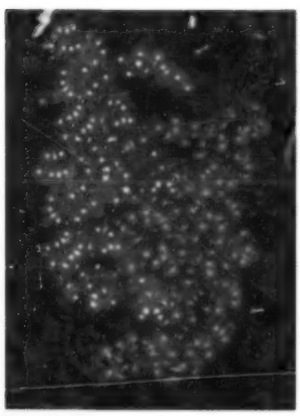
An Effectiveness of Navy Electronic Warfare Systems (ENEWS) simulation of an AEGIS cruiser ("Ticonderoga Class," CG-47 ship) is shown with deployed chaff clouds and an electronic decoy arranged to defend the ship from a wave of antiship cruise missiles. (W. McIntyre, Code 5707)



The Combined Release and Radiation Effects Satellite (CRRES) is designed to get a deeper understanding of several ionospheric and magnetospheric phenomena. Here is the CRRES spacecraft as it appears in orbit. The solar panels support four LASSII antenna booms, which are used to measure electron densities and electric fields. The LASSII loop antenna for measuring magnetic field fluctuations is mounted on the spacecraft side. Chemical canisters for the release experiments are stored in the spacecraft side panels. (P. Rodriguez, Code 4785)

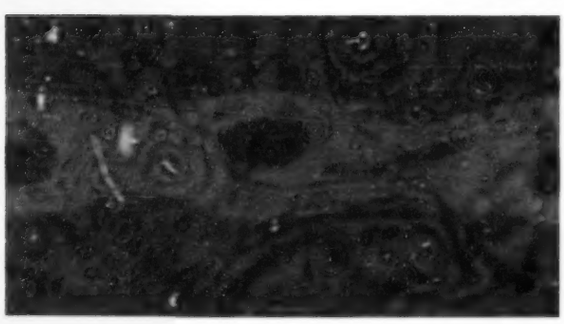


Beam density contours from a particle simulation of a high current, relativistic electron beam propagating in air at atmospheric pressure. The beam is moving from right to left and shows the effects of erosion, instability, and tracking in a channel of reduced air density. The model represents a beam generated by the NRL Super-IBEX experiment. (G. Joyce, Code 4790)

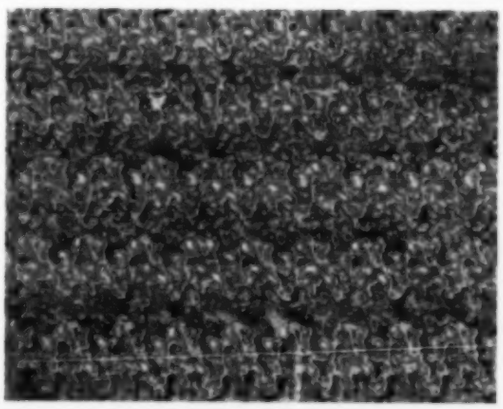


Helical peptides associated in a paired coupling by interdigitating long side chains in a zipper motif. (I. Karle, Code 6030)

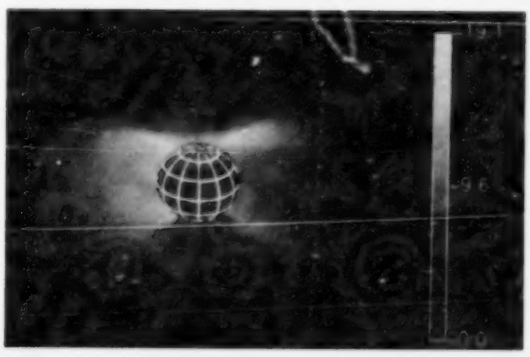
An instantaneous flow visualization from a typical, simulated plane wake by using the NRL finite-difference bluff-body code is shown. One can see streamwise vortices distinctly superimposed to a vortex street in the saddle regions between distorted spanwise rollers. The streamwise vortices appear as legs of horseshoe vortices in response to cross-stream spanwise excitation of the inflowing streams. Vortex reconnection phenomena lead to the formation of unconnected closed vortex loops. This research allows an improved characterization of the underlying fluid-dynamical processes in 3-D bluff-body near-wakes, with important applications for external flows over bodies, such as ships, submarines, torpedoes, and planes. (F.F. Grinstein, Code 4410)



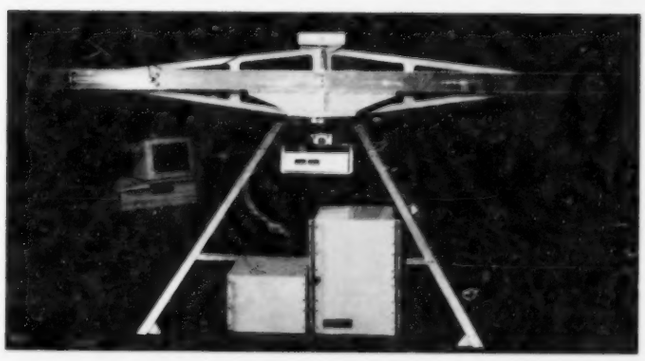
Here the vorticity in a two-dimensional shear layer during the evolution of a strong instability is shown. The shear layer, a region of high velocity gradient, has been subjected to disturbances whose wavelengths are 1/2 and 1/3 of the computational domain. At this stage of the computation, the original shear layer has evolved into two distinct vortices as a result of the dominant 1/2 mode. At later stages of the calculation, the vortices will merge into one as a result of the modulation of the 1/2 mode by the 1/3 mode. (R. Handler, Code 4220)



Scanning tunneling microscopy image of the surface order of a nematic liquid crystal, 4-cyano-4'-hexylbiphenyl, on graphite. The image is a 11.7 nm × 11.7 nm false color plot of raw data taken at room temperature. The high resolution image gives details about the long-range order and the packing of the cyanobiphenyl (head) and the alkyl (tail) groups. The head groups organize in rows containing alternating 'X' and 'I' patterns colored pink in the image. The 'X' represents one cyanobiphenyl group lying flat on the surface, and the 'I' represents another head group lying on its side. The alkyl tail, from a molecule lying on its side, extends down across the blue-colored band and aligns with a tail extending upward from a molecule lying flat in the next row below. The bluish holes in the ordered structure show the graphite substrate. (S. Brandow, D. DiLella, R. Colton, Code 6177, and R. Shashidhar, Code 6090)

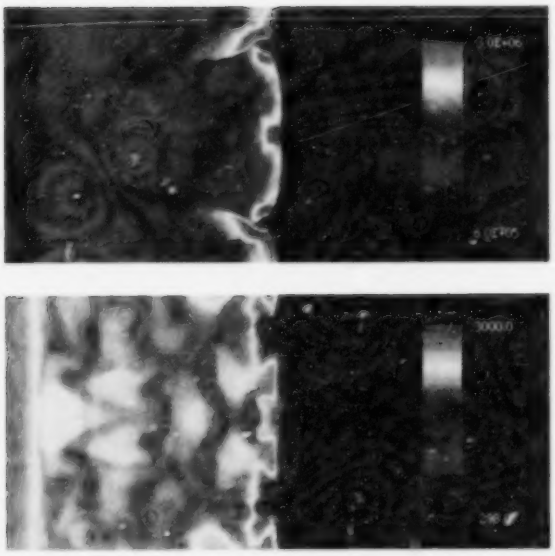


False color extreme ultraviolet image of a model of the Earth's plasmaspheric helium ion emission produced by scattering of sunlight at 304 Å. Helium ions are trapped within the plasmasphere or region of closed magnetic field lines, which extend in this model to 4.25 Earth radii at the magnetic equator or about 60° latitude at the Earth. The Sun is to the left; the Earth's shadow can be seen on the right, passing through the plasmasphere. (R. Meier and S. Thonnard, Code 4140)

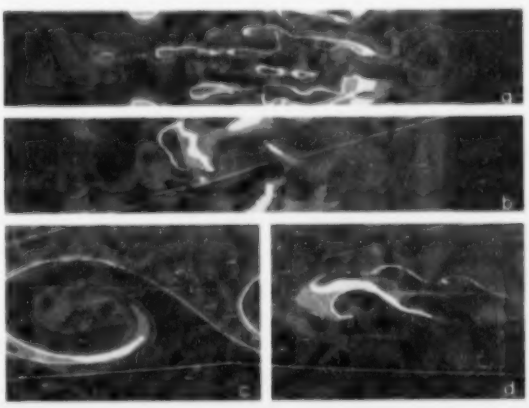


The precision direction-finding system measures the direction-of-arrival of received RF signals with extreme accuracy, extending the technology in direction-finding accuracy by more than two orders of magnitude, from typically 1 to 5 spatial degrees to 0.01 spatial degrees. (R. Oxley, Code 5724)

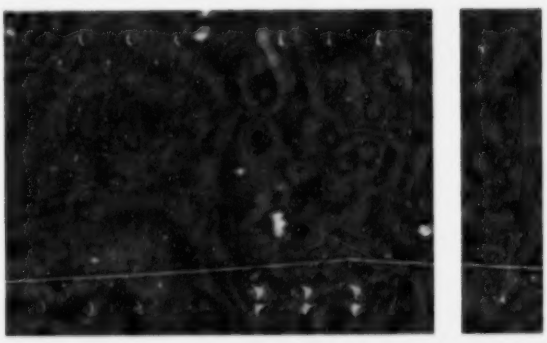
In cooperation, the Space Systems Technology Department and the Laboratory for Computational Physics and Fluid Dynamics developed a towable device, STEMS (Surface TEnsion Measuring System), to spatially measure in situ surface tension with high resolution. STEMS is shown being towed across a ship wake in that experiment. The smoke flare marks the wake edge. Four humpback whales show their interest in the project. (See paper entitled "Development of a Mobile Oceanographic Platform," in this *NRL Review*. (J. Kaiser, Code 8310) 8310)



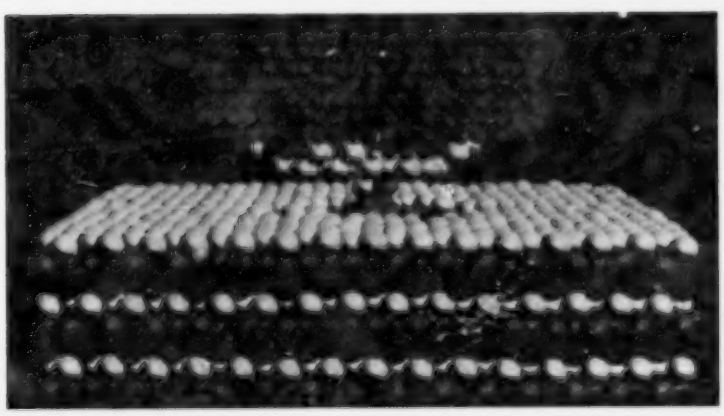
The structure of a propagating detonation: The figure shows that the instantaneous structure of a detonation propagating in a channel is complex and consists of multiple shock waves interacting at the detonation front. The pressure field (top photo) clearly shows the high pressure region (red) where the multiple shock waves interact. The transverse waves (propagating transverse to the direction of propagation of the detonation) are brought out distinctly in the pressure field. The temperature field (bottom photo) indicates that the energy release reactions take place at different distances behind the different shock waves. This is an important factor crucial for sustaining a propagating detonation. (K. Kailasanath, Code 4410)



The development of ionosphere-magnetosphere coupling models: Panels (a) and (b) show the nonlinear evolution of density-gradient-driven plasma interchange instabilities generated in the high latitude ionosphere (a) without and (b) with magnetospheric coupling. Panels (c) and (d) display the evolution of the velocity-shear-driven Kelvin-Helmholtz instability in the high latitude magnetosphere (c) without and (d) with ionospheric coupling. (M. Keskinen, Code 4780)



Molecular graphic representation of two orientations of a DMBC lipid bilayer. (B. Gaber, Code 6090)



Studying the atomic mechanisms of adhesion, nanoindentation, and fracture mechanics. As the nickel tip (red spheres) pulls away from the gold surface, it takes a layer of gold atoms (yellow spheres) with it and pulls a thin neck of gold atoms from the second layer (green spheres). The photo visualizes a molecular dynamics simulation that predicts what will happen when a nickel tip makes contact with a gold surface and is removed again. The simulations were obtained on a Cray supercomputer by Uzi Landman and David Luedtke of Georgia Institute of Technology in collaboration with Nancy Burnham and Richard Colton of the Chemistry Division, who are using an atomic force microscope to measure the tip-surface interactions and to test the theoretical model. (R. Colton, Code 6177)